Technical Report M35

SEDIMENTATION AND NAVIGATION STUDY OF THE MIDDLE MISSISSIPPI RIVER AT GRAND TOWER RIVER MILES 84.0 TO 79.0

HYDRAULIC MICRO MODEL INVESTIGATION

By
Dawn M. Lamm
Robert D. Davinroy
David C. Gordon
Jasen L. Brown
Edward H. Riiff
Edward J. Brauer
Aron M. Rhoads

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APPLIED RIVER ENGINEERING CENTER
FOOT OF ARSENAL STREET
ST. LOUIS, MISSOURI 63118

Sponsored by and Prepared for:
U.S ARMY CORPS OF ENGINEERS – ST. LOUIS DISTRICT

In Cooperation With:
RIVER INDUSTRY ACTION COMMITTEE
ILLINOIS DEPARTMENT OF NATURAL RESOURCES
MISSOURI DEPARTMENT OF CONSERVATION
U.S. FISH AND WILDLIFE SERVICE

Final Report – 2004

INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District initiated a sedimentation and navigation study of the Middle Mississippi River between Miles 84.0 and 79.0. The purpose of the study was to evaluate and propose design modifications to existing stone dike and/or weir structures and the introduction of new structures for the purpose of improving navigation conditions and reducing dredging through the Grand Tower area on the Mississippi River.

Mrs. Dawn Lamm, Hydraulic Engineer, and Mr. Edward Riiff, Engineering Technician conducted the study between January 2004 and August 2004, with assistance provided by Mr. Jasen Brown, Hydraulic Engineer and Mr. Edward Brauer, Engineering Intern, under direct supervision of Mr. David Gordon, Hydraulic Engineer. Other personnel also involved with the study included: Mr. Robert Davinroy, District Potamologist, Mr. Claude Strauser, Chief of the Hydrologic and Hydraulics Branch, Mr. Leonard Hopkins, Project Manager, Mr. David Busse, Chief of the Potamology Section; Mr. Lance Engle, District Dredging Manager; Mr. Dan Erickson, Rivers Project Office; and Ms. Teri Allen, Mr. T. Miller and Mr. Brian Johnson, from the Environmental Branch of the Planning, Programs, and Project Management Division.

Personnel from other agencies involved in the study included: Mr. Scott Stuewe and Mr. Butch Atwood from the Illinois Department of Natural Resources; Ms. Joyce Collins, Mr. Mike Thomas, Ms. Karen Westphal and Mr. John Magera from the U.S. Fish and Wildlife Service; Ms. Valerie Barko, Mr. Mark Boone, Mr. David Ostendorf and Mr. Dave Herzog from the Missouri Department of Conservation.

Personnel representing industry included Mr. Raymond Hopkins from American River Transportation Company, Mr. Sammy Dickey of American Commercial Barge Line and the Chairman of the River Industry Action Committee. Additional participants included Mr. Jack Scott, Mr. Steven Harvey, Mr. Paul McGee, and Mr. Alan Kelly of the Ameren Corporation and Mr. Tom Rider of Bunge North America.

TABLE OF CONTENTS

BACKGROUND

Micro modeling methodology was used to evaluate the existing sediment transport conditions and the impact of various structural design measures to improve navigation conditions in the Grand Tower area of the Middle Mississippi River. The study was funded by the Regulating Works Project in the Hydrologic and Hydraulics Branch of the St. Louis District.

The goal of this study was to reduce dredging and improve navigation conditions in the main channel of the Mississippi River without detrimentally effecting loading/unloading operations at Bunge North America or the operation of the Ameren Corporations Grand Tower Power Station, both located along the Illinois bank of the Mississippi River.

1. Study Reach

Plate 1 is a location and vicinity map of the study reach. The study area was located in Perry County, Missouri and Jackson County, Illinois. The study reach encompassed 5 miles of the Middle Mississippi River, between Miles 84.0 and 79.0. Plate 2 is a 1998 aerial photograph illustrating the characteristics, configuration, and nomenclature of the Mississippi River between Miles 86.0 and 78.0. The reach includes one pipeline suspension bridge, a power plant, two recreational boat ramps, and one loading/unloading facility. The city of Grand Tower is located at Mile 79.8, Tower Rock at Mile 80.0 and the Ameren Corporation Grand Tower Power Station at Mile 81.9.

The right descending bank (RDB) from Mile 86.0 to Mile 84.8 is adjacent to a rock bluff with steeply sloped banks. Some of the bankline is covered with rock, both naturally occurring and artificially placed to protect the railroad track located at the top of the bankline. From Mile 84.8 to Mile 82.5 a large depositional area is present. The RDB behind this sandbar contains 17 rock hardpoint structures and the outlet of Owl Creek. From Mile 82.5 to Mile 81.1, the bank is covered with a substantial amount of rock. The outlet of Brazeau Creek and a boat ramp are located at Mile 81.5. The bluff line and railroad tracks again borders the RDB of the river just downstream of the boat ramp at Mile 81.5. The RDB at Mile 81.1 contains some large rock deposits and steep unprotected slopes. The Tower Rock formation is located at Mile 80.0 and is illustrated in the photograph on Plate 3. This formation contains large rock outcroppings, both emergent and submergent. From Mile 79.8 to Mile 78.0, a large island with a substantial sand and gravel bar and a side channel referred to as Cottonwood Chute is present. The banklines appear steep but stable along the RDB downstream from Tower Rock and adjacent to the Island.

The left descending bank (LDB) from Mile 87.0 to Mile 83.8 contained 8 dikes that had developed downstream bankline roundouts. The LDB is otherwise gently sloped with some vegetation present. At Mile 83.7, Fountain Bluff begins along the LDB and continues along the Mississippi River until Mile 82.4. A loading/unloading operation, owned by Bunge Corporation, is located at Mile 82.4 and the Ameren Corporation Grand Tower Power Station is located at Mile 81.9. The bankline at these facilities is steep but stable. A large depositional area is located between these facilities and continues to Mile 80.9. A rock outcropping is present at Mile 80.9, which supports the Illinois piers of the natural gas pipeline suspension bridge. Downstream of the rock outcropping at Mile 80.9, the LDB is gradually sloped and includes a recreation park. At Mile 80.1, the LDB appears to be reveted. The revetment extends downstream to Dike 79.2 L. Two additional dikes were located in this area. From Dike 79.2 L to the end of the study reach, the LDB is gradually sloped.

The flow patterns, channel alignment, and depositional areas in the Grand Tower study reach are a direct result of the naturally occurring bluffs and rock outcroppings in the area.

The Illinois communities within the study reach are protected by the Degognia and Fountain Bluff Drainage and Levee District upstream from Fountain Bluff and by the Grand Tower Bluff Drainage and Levee District downstream from Fountain Bluff. The Missouri communities between the bluffs are not protected by a levee system.

At the time of this study, the main channel of the Grand Tower study area was comprised of three dike fields and two individual dikes, containing a total of 16 structures, a weir field containing a total of ten structures, and a hard point field containing 17 structures. All dike and weir structures were of stone construction. All dikes and other characteristics of the study reach are shown on Plate 2 and are listed in the following tables.

The following tables detail the approximate dimensions and characteristics of the dikes and weirs within the study reach. (Note: All bed elevations described in this report are referenced to the Low Water Reference Plane (LWRP). The LWRP represents a theoretical water surface elevation profile based upon a low flow of 54,000 cfs. The reference elevation of 0 feet LWRP is based upon the probability that this stage and flow will be exceeded 97% of the time annually.)

Dike/Mile	Estimated Elevation (feet LWRP)	Dike Length
86.4 R	15	350
86.0 L	15	400
86.0 R	15	530
85.9 R	15	500
85.7 L	15	375
85.7 R	15	150
85.5 L	15	280/300
85.5 R	15	400
85.2 L	15	320
85.2 R	15	500
85.1 R	15	325
85.0 R	15	550
84.9 L	15	200
79.5 L	15	175
79.3 L	16	280
79.3 R	16	760
79.2 L	16	200
78.15 L	16	375

Mile	Hardpoint Number	Approximate Elevation (feet LWRP)	Dike Length
84.3 R	17	19	100
84.2 R	16	19	100
84.05 R	15	19	160
83.95 R	14	19	100
83.8 R	13	19	100
83.7 R	12	19	100
83.6 R	11	19	100
83.5 R	10	19	100
83.4 R	9	19	100
83.3 R	8	19	100
83.2 R	7	19	100
83.1 R	6	19	100
83.01 R	5	19	100
82.9 R	4	19	100
82.8 R	3	19	65
82.7 R	2	19	170
82.6 R	1	19	100

Weir / Mile	Approximate Elevation (Feet LWRP)	Weir Length (feet)	Year Built
84.1 L	-15	685	1995
83.9 L	-15	655	1996
83.8 L	-15	820	1996
83.7 L	-15	1250	1996
83.6 L	-15	820	1996
83.5 L	-15	685	1996
83.4 L	-15	795	1996
83.3 L	-15	780	1996
83.1 L	-15	900	1996
83.0 L	-15	840	1996

2. Problem Description

Dredging

Within the Grand Tower study area, there are two repetitive dredging locations. Dredging areas from 1990 to 2003 are shown on Plate 4. Total cost of this dredging has been almost $3 million since 1990. These areas must usually be dredged in alternating years to maintain thalweg depth and channel alignment

The first repetitive dredging site is located along the RDB, between Miles 82.0 and 81.3. This dredge location had averaged approximately 68,500 cubic yards of dredged material a year since 1990, at an average cost of over $131,500 per year. Disposal from this dredging location has been side-cast onto the sandbar located along the LDB.

The second repetitive dredging site is located upstream and adjacent to Tower Rock between Miles 80.6 and 79.9. This dredge location has averaged over 49,000 cubic yards of dredged material a year at an average cost of almost $95,000 per year. Disposal from this dredging location had been typically side-cast along the LDB.

Shoaling Problems

A loading/unloading operation, operated by Bunge Corporation, is located along the LDB, at Mile 82.3 and is shown on Plate 5. Due to a large depositional area along this bankline, this facility has experienced problems when approaching the facility from downstream.

The power plant, operated by Ameren UE, and shown on Plates 5 and 6, and located along the LDB at Mile 81.9, has experienced problems due to the same depositional area that is located from Mile 82.5 to Mile 80.8. During lower water stages, the bar prevents the warm water outflow from reaching the river channel without infiltrating the cold water intakes. Plates 5 through 7 demonstrate this through three different viewpoints. The sandbar forces the warmer water to flow upstream past the cooling water intakes. The water temperature at the cooling water intakes then becomes too high to operate the facility. Ameren Corporation repeatedly dredges a channel for the outflow water but this is usually repetitive and a short-lived resolution. Many times the power plant must shut down until river elevations are sufficient to restore operations. From December 2002 through early November 2003, the plant was closed due to insufficient water levels a total of 71 days. Fourteen of those days were during a time of peak energy demand.

During the middle of this study, Ameren Corporation was granted permission to build a dike beginning at their facilities outfall structure and across the adjacent sand bar. The dike was built with a top elevation of +15 feet LWRP and is approximately 385 feet long. The purpose of this dike was to create a solid barrier to prevent warm outfall water from flowing upstream during low water events and mixing with the cooling water at the intakes. This dike was then incorporated into tests done on the Micro Model. Ameren Corporation was aware that test results might require them to modify or remove the structure.

3. History

1881

The earliest historical topographic and hydrographic data found regarding this area on the Middle Mississippi River was from 1881 (Plate 8). According to this survey, the main channel thalweg through Fountain Bluff Bend was located along the RDB. A sandbar with a side channel was also located along the LDB of this bend. The channel from Mile 83.0 to Mile 80.0 was very similar to the present day channel due to the rock bluffs located along both sides of the river that restricted meandering. However, downstream of Mile 80.0, the channel was split with a large island present. This island was over 6000 feet wide. The channel thalweg was located in what appeared to be the smaller channel along the LDB. The second channel along the RDB eventually developed into the modern day Cottonwood Chute. The main channel is now located through the middle of the island. The LDB has since filled in and is located behind the levee.

1908

The 1908 historical topographic and hydrographic survey is shown on Plate 9. Differences in this reach of river since 1881 include a slight migration of the sandbar at Fountain Bluff Bend towards the RDB. However, the channel thalweg was still located along the RDB. In addition, it appeared that the navigation industry had begun to use the channel along the RDB below Mile 80.0 and in the region of Grand Tower Island. A sandbar had also formed in the center of the channel at Mile 79.0.

1928

Plate 10 is a 1928 aerial photograph of the study reach. The study reach had not changed significantly. The sandbar along the LDB at Mile 84.7 was still present and appeared to have become slightly vegetated. The sandbar at the channel split at Mile 79.0 had grown in size and the channel thalweg appeared to favor the route along the RDB. There were no other significant changes in the study reach.

1956

The 1956 Hydrographic Survey is shown on Plate 11. This was the first comprehensive hydrographic survey available for the study reach. The rivers bathymetry is very similar to the current state of the river. A difference between this survey and past surveys/photographs was the development of a single defined channel around Fountain Bluff Bend. At the time of this survey, this area contained a sandbar at the tow of the bend along the RDB and the channel thalweg along the LDB. The side channel and island, which was located along the outside of the bend in previous surveys, has lost its connectivity to the Mississippi River and is now part of the bankline. The channel thalweg then crossed to the RDB at Mile 82.8. A large sandbar was present along the LDB from Mile 82.2 to Mile 80.8. The channel thalweg then moved from the RDB at Mile 81.1 to the rock point along the LDB at Mile 80.8 and then back to the RDB at Mile 80.5. The natural gas pipeline suspension bridge crossed the Mississippi River at Mile 80.8. The channel thalweg was along the RDB towards Tower Rock and deflected off of the rock structure towards the LDB where it remained for the remainder of the study reach. A shoal with some island development was also present from Mile 79.9 to the end of the study reach. A closure structure had been placed at the upstream end of the remnant channel separating Grand Tower Island and the Illinois bankline. A new island formed that divided the main channel along the LDB from Cottonwood Chute. Overall, the channel alignment was very similar to the present day.

1969/1970

The 1969/1970 Hydrographic Survey is shown on Plate 12. In this survey, the upstream reach of the study was shallow with a narrow channel thalweg along the LDB. The sandbar and/or pointbar in the Fountain Bluff Bend had increased in width and length and the channel thalweg along the LDB was shallower than past surveys. A sandbar was present along the LDB from Miles 82.3 to 80.8 and from Miles 80.7 to 79.6. Downstream of Tower Rock the channel thalweg was extremely deep. A sandbar and island was also present along the RDB from Mile 79.9 to beyond the end of the study reach.

1977

The 1977 Hydrographic Survey is shown on Plate 13. The channel thalweg was still located along the LDB in the upstream reach of the study with some shoaling along the RDB. The sandbar and/or pointbar in the Fountain Bluff Bend appeared to have stabilized and had not changed in width or length. A sandbar was present along the LDB from Miles 82.3 to 80.7 and then from Miles 80.8 to Mile 79.7. The area immediately downstream of Tower Rock was very deep. An island and sandbar was present along the RDB from Mile 80.0 to the end of the study reach.

1987/1988

The 1987/1988 Hydrographic Survey is shown on Plate 14. The channel thalweg at the beginning of the study reach had widened with occasional shoaling present. The sandbar and/or pointbar in the bend from Miles 85.0 to 82.5 appeared to experience additional deposition with the channel thalweg along the LDB becoming slightly deeper. The channel thalweg along the RDB downstream of Mile 82.0 had become narrower and shallower with only a small scour area located at Mile 82.1. The sandbar was still present along the LDB from Miles 82.2 to 80.8 and Miles 80.7 to 79.6. The channel thalweg downstream of Tower Rock was very deep as it crossed to the LDB where it remained until the end of the study reach. The island and sandbar located along the RDB downstream of Tower Rock appeared to have increased in size.

1996

The 1996 Hydrographic Survey is shown on Plate 15. The 1996 Hydrographic Survey indicated that the beginning of the study reach had become deeper and wider. Due to the construction of ten Bendway Weirs, the channel thalweg through Fountain Bluff Bend also had many areas that exhibited increased depth and width. The ten weirs were constructed in 1995 and 1996, along Fountain Bluff from Miles 84.1 to 83.0 and are evident in the survey. These weirs were built to an elevation of –15 feet LWRP. The channel thalweg crossed to the RDB at Mile 82.7. A sandbar was still present along the LDB between Miles 82.3 and 81.0. The channel thalweg then crossed to the LDB where it intersected the rock point at Mile 80.8. Downstream of Tower Rock the channel scoured a large area as it crossed to the LDB. The channel then remained along the LDB to the end of the study reach. The Island along the RDB downstream of Tower Rock had increased in size, with additional shoaling observed.

2001

The 2001 Hydrographic Survey is shown on Plate 16. The channel appeared shallower than on the previous surveys upstream of Fountain Bluff, including a shoaling area that extended into the channel from Mile 84.7 to 84.4. Seventeen Hard Point structures were built along the RDB from Mile 85.0 to Mile 82.6 in early 1997 for environmental enhancement. Deep scour holes existed between and beyond the last five weirs. At the end of the weir field the channel crossed to the RDB where another deep area existed.

The channel thalweg remained along the RDB until reaching an outcropping at Mile 81.2 where a deep scour hole formed. A sandbar existed along the LDB from Mile 82.6 to Mile 80.9. The channel thalweg then made a short crossing into another rock outcropping along the LDB at Mile 80.8, where a deep scour hole formed. The channel then made another short crossing back to the RDB. At Mile 80.5 and adjacent to the channel thalweg, the RDB contained both deep scour holes and evidence of shallow rock projections. Beyond Tower Rock at Mile 80.1 the channel became extremely deep as the channel crossed to the LDB. A sandbar existed along the LDB from Mile 80.8 to Mile 79.7. From Mile 79.6 through the remainder of the study reach, the channel thalweg was located along the LDB with a sandbar and island existing along the RDB.

2003

A 2003 Aerial Photographs is shown on Plate 17 at a water elevation of +3.6 feet LWRP according to the Red Rock Landing, Missouri gage on October 15, 2003. In this photograph the areas of shoaling were evident due to the low water stage. The problem that Ameren has with their outfall channel losing connectivity with the river is shown as well as the channel that the company dredged in the past from their outfall across the sandbar. A U.S. Army Corps of Engineers channel maintenance dredging operation was captured in progress at Mile 80.2 near the LDB. This dredging area is designated as the second dredging location on Plate 3.

2004

The 2004 Sweep Survey is shown on Plate 18. This survey was performed during low water and only covered areas with depths below –6 feet LWRP. This survey was taken between Miles 85.0 and 78.0. At the beginning of this survey the channel thalweg was located along the LDB with slight scour off of the ends of Dikes 85.2 and 84.9. The channel thalweg then deepened along the LDB at Mile 84.7 as it approached the weir field. The channel thalweg crossed from the LDB to the RDB downstream of the weir field. From Mile 82.5 to 82.3, a scour area had formed along the LDB. The channel then remained along the RDB until Mile 81.2, where it crossed to the LDB. A rock outcropping was indicated along the RDB at Mile 81.2 with a deep scour hole just downstream.

A split channel existed when the thalweg crossed from the rock outcropping at Mile 80.8 to the RDB where it intersected Tower Rock. A secondary channel existed along the RDB. This secondary channel crossed some additional rock formations at Mile 80.4 and 80.3. Downstream of these rock formations, there existed some deep scour holes. Shoaling existed at Mile 80.5 between the channel thalweg and the secondary channel. Downstream of Tower Rock the channel was extremely deep. The channel crossed from Tower Rock to the LDB and remained along the LDB throughout the remainder of the study reach.

4. Field Observations

Personnel from the Applied River Engineering Center inspected the study reach by shallow draft boat and helicopter. The site visits are described below with the water surface elevation referenced to LWRP at the Red Rock Landing, Missouri gage.

+1.5 feet LWRP (November 3, 2003)

The study reach was visited by boat on November 3, 2003, to record field observations and measurements during lower water conditions. The data collected at the site included general observations about the channel and structures within it. The following is a description of the data collected:

The Mississippi River channel was entered from a boat ramp along the RDB at approximately Mile 81.4. Due to the low river level, the shallow draft boat was unable to travel up the channel that the power plant used for their water intakes. The collage of photographs on Plate 7 was taken from the bankline and shows the water intake side channel and sandbar with the Mississippi River and the Missouri bankline in the background. Plate 5 shows a picture of the power plant and the various water channels associated with it. The LDB in this area mainly consisted of sand with some medium to large gravel and cobbles. The sandbar consisted mainly of sand and small gravel.

A picture of the Bunge Loading Facility is shown on Plate 5. The Mississippi River at the downstream end of this facility was very shallow. The remnant of an old sunken barge was located along the bankline at the downstream end of the facility.

The banklines along Fountain Bluff were stable and contained many large boulders as shown on Plate 6. The hardpoint structures and point bar along the inside of the bend at Mile 84.0 appeared to have experienced some degradation. The point bar contained sand and large gravel.

The remainder of the RDB downstream to Tower Rock was steep but stable with some naturally occurring boulders and some revetment present. Due to the lower water conditions, much of rock formation at Tower Rock was visible. This formation has a gradual slope at its base and the face of the rock formation contains a nearly vertical wall to the top. Surrounding rock formations were visible at or just below the water surface.

+3.5 feet LWRP (February 13, 2004)

The study reach was visited by helicopter on February 13, 2004. From this perspective many things could be seen that would not have been obvious or visible from a boat.

The most noted observation, shown on Plate 3, was the magnitude of the formation at Tower Rock. From this vantage point, the many layers and depths of rock are visible. Additional observations included the size of the shoaling impacting the power plant and loading facility, shown on Plate 18.

5. Meeting with Representatives

On April 19, 2004, representatives from Ameren Corporation visited the Applied River Engineering Center to view the Grand Tower Micro Model (Plate 19). Representatives included Mr. Jack Scott, Mr. Steve Harvey, Mr. Paul McGee and Mr. Alan Kelly. Problems that were experienced at the Ameren Corporation Grand Tower Power Station were discussed. Possible alternatives that may be implemented in the Grand Tower area and the effects these alternatives could have on the power plant's water intake and outfall channel were also discussed.

6. Study Purpose and Goals

The purpose of the study was to evaluate and propose design modifications to existing stone dike and/or weir structures and the introduction of new structures. These structures were evaluated on their ability to improve navigation conditions and reduce repetitive dredging through the Grand Tower area on the Mississippi River. An additional purpose of the study was to evaluate each design's effect on the sandbar located in front of the Bunge North America loading/unloading facility and the Ameren Corporation's Grand Tower Power Station. Engineers sought to improve navigation conditions without creating negative impacts to the facilities. Navigation throughout the Grand Tower area will improve and become safer if dredging can be reduced. The federal government may save millions of dollars in dredging and operation costs.

MICRO MODEL DESCRIPTION

1. Scales and Bed Materials

In order to investigate the sediment transport issues described previously, a physical hydraulic micro model was designed and constructed. Plate 20 is a photograph of the hydraulic micro model used in this study. The model employed a horizontal scale of 1 inch = 800 feet, or 1:9600, and a vertical scale of 1 inch = 55 feet, or 1:660, for a 14.5 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those of the prototype. The bed material was granular polyester urea, Type II, with a specific gravity of 1.47.

2. Appurtenances

The micro model insert was constructed according to the 1998 high-resolution aerial photography of the study reach shown on Plate 2. The insert was then mounted in a standard micro model hydraulic flume. The riverbanks of the model were constructed from dense polystyrene foam, and modified during calibration with oil-based clay. The slope of the model was 0.0038 in/in. River training structures in the model were made of galvanized steel mesh.

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to automatically control the flow of water and sediment into the model. Discharge was monitored by a magnetic flow meter interfaced with the customized computer software. Water stages were manually checked with a mechanical three-dimensional point digitizer. Resultant bed configurations were measured and recorded with a three-dimensional laser digitizer.

MICRO MODEL TESTS

1. Model Calibration

The calibration of the micro model involved the adjustment of water discharge, sediment volume, model slope, and entrance conditions of the model. These parameters were refined until the measured bed response of the model was similar to that of the prototype.

A. Micro Model Operation

In all model tests, a steady state flow was simulated in the Middle Mississippi River channel. This served as the average design energy response of the river. Because of the constant variation experienced in the prototype, this steady state flow was used to theoretically analyze the ultimate expected sediment response. The flow was held steady at a constant flow rate of 2.5 GPM during model calibration and for all design alternative tests. The most important factor during the modeling process is the establishment of an equilibrium condition of sediment transport. The high steady flow in the model simulated an average energy condition representative of the river's channel forming flow and sediment transport potential.

B. Prototype Data and Observations

To determine the general bathymetric characteristics and sediment response trends that existed in the prototype, several present and historic hydrographic surveys were examined. Plates 8 through 13 and 15 are plan view hydrographic survey maps of the Mississippi River from 1956, 1969/1970, 1977, 1987/1988, 1996, 2001 and 2004 respectively. In the latest surveys, the thalweg of the main channel was located in the same general alignment.

The bathymetry of the most recent prototype surveys (1996, 2001 and 2004) were very similar to each other and were used to calibrate the micro model. These trends are as follows:

- Through the Weir Field at Miles 84.7 L to 83.0 L the channel exhibited scour holes that reached depths below –40 feet LWRP. However, a shallow area was present between Weir 83.8 and Weir 83.6, where the radius of the bend increases for a short distance.

- The channel crossing was located between Weir 83.3 and Mile 82.5. This crossing maintained depths below –20 feet LWRP.

- From Mile 82.5 to 82.3, a scour area had formed along the LDB with the majority of depths reaching to below –30 feet LWRP.

- The channel then remained along the RDB until Mile 81.2, where it crossed to the LDB at Mile 80.8. This abrupt crossing is caused by a rock outcropping near Mile 81.2. A deep scour hole just downstream of the outcropping reached depths below –50 feet LWRP.

- Another scour hole with depths to –50 feet LWRP was observed at Mile 80.8 along the LDB adjacent to another rock outcropping.

- A variable split channel is formed as the channel thalweg crossed to the RDB from Mile 80.8 and intersected Tower Rock. A smaller channel along the RDB abuts some additional rock formations at Mile 80.4 and 80.3. Downstream of these small rock formations there existed some scour holes where depths reached to below –40 feet LWRP. The 1996 and 2001 surveys showed less of a split channel formation and more of a channel crossing. The 2004 survey showed a distinct split channel with an obvious middle bar.

- The middle bar or crossing had varying heights and was located at Mile 80.5 between the split channel. Depths of this area ranged from less then –10 feet LWRP to –20 feet LWRP. This was the most variable area in the reach.

- Downstream of Tower Rock the channel was extremely deep with depths approaching -100 feet LWRP.

- The channel crossed from Tower Rock to the LDB and remained along the LDB throughout the remainder of the study reach.

- In the study reach, there are four predominate sandbars: along the RDB from Miles 85.0 to 82.6; along the LDB from Miles 82.3 to 80.9; along the LDB from Miles 80.7 to 79.6; and along the RDB from Miles 79.7 to 77.8. These sandbars each had a top elevation that fluctuated from a –2 feet LWRP up to and above a +10 foot LWRP.

C. Base Test

Model calibration was achieved once it was determined through qualitative comparisons that the prototype trends were similar to several surveys of the model. The resultant bathymetry of this calibrated bed response served as the base test of the micro model (Plate 21). This base test survey served as the comparative bathymetry for all design alternative tests.

Results of the micro model base test bathymetry and a comparison to the combined trends of the 1996, 2001 and 2004 prototype surveys indicated the following:

- The bathymetric trends in the weir field were similar to that of the prototype, with exception of slightly shallower depths.

- The channel thalweg did not completely shift towards the ends of the downstream weirs as shown in the prototype. Although the crossing was in the same position, depths were slightly shallower.

- The scour hole along the RDB between Miles 82.4 and 82.2 was nearly the same size and depth in the basetest as in the prototype surveys.

- Shoaling was indicated from Mile 82.0 to 81.4 towards the center of the channel and along the RDB of the basetest. However, this is one of the bi-annual dredging locations, which is not shown on the prototype surveys since it had been dredged to maintain the navigation channel.

- The scour patterns around the rock outcroppings along the RDB upstream of Mile 81.0 and along the LDB downstream of Mile 81.0 are almost identical to those shown in the prototype survey. However, the crossing from the RDB to the LDB at Mile 81.0 is slightly shallower in the basetest.

- The shoaling located near the RDB from Mile 81.0 to 80.6 is in the correct location but is higher in the basetest when compared to the prototype surveys. However, this is one of the bi-annual dredging locations and would not necessarily show up on the prototype surveys since it had been dredged to maintain the navigation channel. However, small bar is actually present on the 2004 sweep survey.

- The scour patterns along the RDB at Mile 80.4 are slightly larger in the basetest.

- The scour hole pattern downstream of Tower Rock at Mile 80.0 is also slightly wider then shown on the prototype surveys. It is also not as deep as indicated on the prototype surveys.

- The channel thalweg is slightly deeper from Miles 79.5 to 78.7 in the basetest.

- All four sandbars are located in the same position and have the same heights as the prototypes.

Overall, the trends of the model as observed in the base test were similar to those observed from the prototype surveys.

2. Design Alternative Tests

Twenty-five design alternative plans were model tested to examine methods of modifying the sediment transport response trends that would eliminate dredging in the main channel. Most design alternatives included the addition of structures such as chevrons, dikes or weirs. The effectiveness of each design was evaluated by comparing the resultant bed configuration to that of the base condition. Impacts or changes induced by each alternative were evaluated by observing the sediment response of the model. Each design was also evaluated on its impact to the Bunge and Ameren facilities. Designs that could potentially increase problems at these sites were eliminated. Designs that would decrease dredging while either having little impact or create positive effects at the facilities were desired.

Alternative 1: Plate 22

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Chevrons	3	82.5 82.4 82.35	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced	Slightly Reduced on the Downstream End	Improved depths	No effect	This test greatly improved depths at Bunge but did not have enough effect on other problem areas to be considered

Alternative 2: Plate 23

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Chevrons	2	82.5 82.3	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced	Slightly Reduced on the Downstream End	Increased depths	No effect	A slight depositional area formed at the crossing at Mile 82.6.

Alternative 3: Plate 24

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Chevrons	3	82.5 82.3 82.1	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced	Slightly Reduced on the Downstream End	Increased depths	No effect	A depositional area formed at the crossing at Mile 82.6.

Alternative 4: Plate 25

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Chevrons	3	82.5 82.3 82.1	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Moderately Reduced	Moderately Reduced	Increased depths	No effect	A slight depositional area formed at the crossing at Mile 82.6.

Alternative 5: Plate 26

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dike	1	82.8	RDB	800	+15
Chevrons	1	82.2	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced	No effect	Increased depths	No effect	A slight depositional area formed at the crossing at Mile 82.6. A split channel formed between Mile 82.2 and 81.2.

Alternative 6: Plate 27

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weirs	2	82.9 82.8	LDB	1000 1200	-15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced Thalweg shifted towards LDB	Slightly Reduced on the Downstream End	Increased depths	No effect	A slight depositional area formed at the crossing at Mile 82.6. The thalweg shifted to the center of the channel between Miles 82.2 and 81.4 with deposition appearing along the RDB.

Alternative 7: Plate 28

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weirs	2	82.9 82.8	LDB	1000 1200	-15
Chevrons	1	82.5	Near the LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
No Effect / Slightly increased Thalweg shifted	No effect	Increased depths	No effect	A slight depositional area formed in the crossing at Mile 82.6. The thalweg shifted to the center of the channel between Miles 82.2 and 81.4 with a large amount of deposition appearing along the RDB at Mile 81.3.

Alternative 8: Plate 29

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	4	82.3 82.15 82.0 81.8	RDB	650 660 900 950	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly reduced Thalweg shifted towards LDB	Increased at the Upstream End and Decreased at the Downstream End	Significantly Increased depths	Significantly Increased depths	The thalweg shifted towards the LDB between Miles 82.3 and 81.0 with deposition appearing along the RDB.

Alternative 9: Plate 30

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	6	82.85 82.7 82.5 82.3 82.2 82.0	RDB	1000 800 600 750 950 1300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments

Slightly reduced	Reduced	Significantly Increased depths	Significantly Increased depths	The thalweg shifted towards the LDB between Miles 82.8 and 81.0 with some deposition appearing along the RDB. Scour holes developed off of the ends of the lower 5 dikes. The scour off of the rock projection along the LDB at Mile 80.8 increased.

Alternative 10: Plate 31

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	6	82.85 82.6 82.4 82.15 81.8 81.5	RDB	1000 800 550 800 1000 1250	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Significantly reduced	Significantly reduced	Increased depths	Increased depths	The thalweg shifted towards the LDB between Miles 82.8 and 81.0 with some deposition appearing along the RDB and LDB. Scour holes developed off of the ends of the upper three dikes. The scour off of the rock projection along the LDB at Mile 80.8 as well as scour along the LDB between Miles 79.6 and 78.6 increased significantly.

Alternative 11: Plate 32

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP

Weirs	2	82.5 82.3	RDB	450 600	-15
Chevron	1	82.0	Near LDB	300 x 300	+15
Dike	1	81.8	LDB	400	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Reduced	Slightly Reduced	No effect	Slight effect	A slight decrease in height and width of the sandbar in front of the Ameren Facility.

<u>Alternative 12:</u> Plate 33

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weirs	2	82.5 82.3	RDB	450 600	-15
Chevron	2	82.0 81.9	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Reduced	Increased at the Upstream End and Decreased at the Downstream End	Increased depths	Increased depths	Minimized the upstream end of the sandbar but did not produce a continuous side channel to the river. The channel thalweg shifted to the left with some deposition along the RDB.

<u>Alternative 13:</u> Plate 34

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP

Weirs	5	82.5 82.3 82.15 82.0 81.8	RDB	1050 1100 1200 1350 1300	-15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly Reduced	Slightly Reduced on the Downstream End	Slightly Increased depths	No effect	Was not effective in reducing dredging locations or assisting facilities.

Alternative 14: Plate 35

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weirs	2	82.5 82.3	RDB	450 600	-15
Chevron	1	82.0	Near LDB	300 x 300	+15
Dikes	2	81.8	LDB	400 400	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly Reduced	Reduced	Slightly Increased depths	No effect	Increased depths some at upper end of sandbar but not significantly. Dredging was reduced between Miles 80.6 and 79.9.

Alternative 15: Plate 36

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	2	82.55 82.45	RDB	400 400	+15
Chevrons	2	82.0 81.9	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Significantly Reduced	Reduced	Increased depths	Increased depths	This alternative increased depths for the facilities but still left some deposition along the RDB at Mile 81.6. The angle of the two new dikes may induce damage to the bankline during high water events.

Alternative 16: Plate 37

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	2	82.6 82.4	RDB	650 600	+15
Chevrons	3	82.2 82.1 82.0	Near LDB	300 x 300	+15

Effect on Dredging At	Effect on Dredging At	Effect at Bunge	Effect at Ameren	Additional Comments

Miles 82.0 to 81.3	Miles 80.6 to 79.9			
Slightly Reduced	Slightly Reduced	Increased depths	Increased depths	This alternative increased depths for both facilities but may cause access problems for Bunge. It did not create a side channel with a downstream connection to the river. The thalweg shifted towards the LDB.

<u>Alternative 17:</u> Plate 38

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dike	1	82.6	RDB	750	+15
Chevrons	7	82.2 82.1 81.95 81.8 81.7 81.55 81.4	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly Reduced	Reduced	Increased depths	Increased depths	This alternative increased depths for both facilities but may cause access problems for Bunge. A side channel was formed but it did not have a downstream connection to the river.

<u>Alternative 18:</u> Plate 39

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dikes	2	82.6 81.85	RDB LDB	700 400	+15
Chevrons	3	82.2 82.05 81.95	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly Reduced	Significantly Reduced	Increased depths	Increased depths	This alternative increased depths for both facilities but may have caused access problems for Bunge. A side channel was formed but it did not have a downstream connection to the river. Additional deposition appeared along the RDB at Mile 82.3 to 82.0. Thalweg shifted slightly towards the LDB.

Alternative 19: Plate 40

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Dike	1	81.85	LDB	400	+15
Chevrons	3	81.95 81.65 81.4	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
No Effect	Slightly Reduced	No Effect	No Effect	This alternative had no positive effects on the sandbar at the facilities. A narrow channel developed through the first dredging site but it was not sufficient to accommodate navigation.

Alternative 20: Plate 41

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Rootless Dikes	2	81.7 80.5	LDB	350 500	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Significantly Reduced	Slightly Reduced	No Effect	Increased Depths	Depths were increased near Ameren's facility but a continuous side channel was not created. Thalweg shifted slightly towards the LDB.

Alternative 21: Plate 42

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weir	1	82.4	RDB	400	-15
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Rootless Dikes	2	81.7 81.45	LDB	450 500	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Moderately Reduced	Slightly Reduced	No Effect	Increased Depths	Depths were increased near Ameren's facility but a continuous side channel was not created.

<u>Alternative 22:</u> Plate 43

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weir	2	82.5 82.4	RDB	600 600	-15
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Rootless Dike	1	81.7	LDB	350	+15
Dike	1	80.5	LDB	500	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Moderately Reduced	Moderately Reduced	No Effect	Slightly Increased Depths	Depths were slightly increased near Ameren's facility but a continuous side channel was not created. A slight split channel formed near Mile 82.0

<u>Alternative 23:</u> Plate 44

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weir	3	82.5 82.4 82.3	RDB	600 600 650	-15
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Dike	1	80.5	LDB	500	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Moderately Reduced	Moderately Reduced	No Effect	Increased Depths	Depths were slightly increased near Ameren's facility but a continuous side channel was not created.

<u>Alternative 24:</u> Plate 45

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weir	3	82.5 82.4 82.3	RDB	600 600 650	-15
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Dikes	3	81.65 80.7 80.6	LDB	300 550 450	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Slightly Reduced	Significantly Reduced	Slightly Increased Depths	Increased Depths	Depths were increased near Ameren's facility and a continuous side channel was created.

<u>Alternative 25:</u> Plate 46

Type of Structure	Number of Structures	Miles	LDB or RDB	Dimensions in Feet	Height in Feet LWRP
Weir	2	82.5 82.4	RDB	550 500	-15
Notched Dike	1	81.85	LDB	950 with a 200 notch	+15
Dikes	3	81.65 80.7 80.6	LDB	300 350 350	+15
Chevron	1	82.0	Near LDB	300 x 300	+15

Effect on Dredging At Miles 82.0 to 81.3	Effect on Dredging At Miles 80.6 to 79.9	Effect at Bunge	Effect at Ameren	Additional Comments
Moderately Reduced	Significantly Reduced	Slightly Increased Depths	Increased Depths	Depths were increased near Ameren's facility and a continuous side channel was created. Both dredging areas were significantly reduced.

CONCLUSIONS

1. Summary

Twenty-five alternative design tests were conducted in this study. All alternatives sought to reduce or eliminate repetitive dredging in the navigation channel along the RDB between Miles 82.0 and 81.3 and along the LDB between Miles 80.6 and 79.9. The designs also sought to reduce the upstream portion of the sandbar along the LDB between Miles 82.5 to 80.8 to improve conditions at the Bunge and Ameren facilities. Another goal was to create additional habitat through the creation of off-channel bathymetric diversity, such as side channel development. A standard set of dikes along the Illinois bankline near both facilities would decrease the contraction width and help eliminate dredging between Miles 82.0 and 81.3. However, designs such as this might increase the sedimentation problems experienced by both Bunge and Ameren. None of the designs tested in the model created additional problems for either Bunge or Ameren.

During alternative testing on this model, the Ameren Corporation constructed the previously mentioned dike at Mile 81.85 L. This structure was constructed to +15 LWRP and was approximately 385 feet long. Once constructed, this structure was incorporated into alternative testing. Some modifications to the structure were investigated as well as the current structure configuration.

An additional feature that was not tested but was discussed with industry representatives and environmental partners was the notching of Dike 81.85 L near the bankline. A notch with an invert elevation of around +5 feet LWRP may promote the development of a secondary side channel during higher water stages. This secondary side channel should further assist the power plant with their water intake and outfall problems. The notch should be approximately 100 feet wide.

2. Analysis

Designs implemented in the model sought to reduce dredging by either moderate or significant amounts in both problem areas of the navigation channel. Those designs that had no effect or only had a slight reduction in dredging at one of the two sites were discarded. The following table summarizes the effect of each design.

Alt	Effect on Dredging at Miles 82.0 to 81.3				Effect on Dredging at Miles 80.6 to 79.9				Effect at Bunge		Effect at Ameren		Shift In Thalweg Location
	None	Slight Reduction	Moderate Reduction	Significant Reduction	None	Slight Reduction	Moderate Reduction	Significant Reduction	None	Increased Depths	None	Increased Depths	
1		X				X				X	X		
2		X				X				X	X		
3		X				X				X	X		
4			X				X			X	X		
5		X			X					X	X		X
6		X				X				X	X		X
7	X				X					X	X		X
8		X					X			X		X	X
9		X					X			X		X	X
10				X				X		X		X	X
11			X			X			X			X	X
12			X			X				X		X	X
13		X				X				X	X		X
14		X					X			X	X		
15				X			X			X		X	X
16		X				X				X		X	X
17		X					X			X		X	X
18		X						X		X		X	X
19	X					X				X		X	X
20				X		X			X			X	X
21			X			X			X			X	
22			X				X		X			X	X
23			X				X		X			X	
24		X						X		X		X	
25			X					X		X		X	

Designs implemented in the model from Alternative 18 and on incorporated the 400-foot long dike that Ameren constructed during the study. These design alternatives sought to utilize this dike in conjunction with other structures to address the dredging issues. As shown in the previous table, six designs had either a moderate or significant reduction in dredging at both sites in the navigation channel. Those designs were Alternatives 4, 10, 15, 22, 23, and 25. Analysis of each of these alternatives follows.

- Alternative 4: The model indicated a moderate reduction in dredging at both sites. It increased depths at Bunge but did not have an effect at Ameren. To achieve these results the upstream most chevron was placed in a position where it will most likely affect navigation traffic. Therefore, this design will not be feasible.

- Alternative 10: The model indicated a significant reduction in dredging at both sites. It also significantly increased depths along the banklines at both facilities. However, the design consisted of 6 dikes with a combined length of 5400 feet placed in the current channel thalweg along the RDB. This design would probably be the most expensive alternative to construct. Furthermore, the concept would require a major realignment of the navigation channel towards the LDB. Therefore, this design will not be feasible.

- Alternative 15: The model indicated a significant reduction in dredging at the upstream site and a moderate reduction at the downstream site. It also significantly increased depths along the banklines at both facilities. To achieve these results, downstream angled dikes were utilized in the channel thalweg near Mile 82.5. Not only would these dikes create a hazard to navigation, the downstream angle of the dikes may induce damage to the banklines during high water events. Therefore, this design will not be feasible.

- Alternative 22: The model indicated a moderate reduction in dredging at both sites. It increased depths at Ameren but did not have an effect at Bunge. However, the model indicated that the upstream weir configuration might create split channel with a hazardous middle bar around Mile 82. Therefore, this design will not be feasible.

- Alternative 23: The model indicated a moderate reduction in dredging at both sites. It increased depths at Ameren but did not have an effect at Bunge.

- Alternative 25: The model indicated a moderate reduction in dredging at the upstream site and a significant reduction at the downstream site. It also increased depths along the banklines at both facilities.

The model showed that without drastically changing the position of the navigation channel, the only feasible means to decrease dredging in the navigation channel was through the use of dike and chevron structures along the LDB. To implement these structures without negatively impacting the Bunge and Ameren facilities small bendway weirs must be utilized near Mile 82.5R. The weirs were utilized to redistribute flow towards the LDB so the emergent structures could encourage secondary channel development. The model showed that the designs in Alternatives 23 and 25 were most effective at establishing depth in both the navigation channel and at the facilities along the LDB, without obstructing the navigation channel or drastically shifting the channel thalweg.

3. Recommendations

Of Alternatives 1 through 25, Alternatives 23 and 25 produced the most favorable results by eliminating the dredging problems and reducing the upstream portion of the sandbar along the LDB. However, Alternative 25 created the most environmental benefits with the possible creation of a secondary channel that has both upstream and downstream connectivity with the main channel. This design consisted of adding two weirs along the RDB, and four dikes and one chevron near the LDB.

- Two weirs at Miles 82.5 R, and 82.4 R, with lengths of 550 and 500 feet respectively, at a height of -15 feet LWRP.

- A notched extension to Ameren's existing dike at Mile 81.85. The completed dike will be 950 feet long with a 200-foot long notch with an invert elevation to the bed.

- Three dikes at Miles 81.65, 80.7, and 80.6, with lengths of 300, 350, and 350 feet respectively, all near the LDB at a height of +15 feet LWRP.

- One chevron at Mile 82.0, near the LDB, 300 foot wide and 300 foot long at a height of +15 feet LWRP.

When this design is constructed, it may be built in phases to assist with cost and to allow for gradual changes for tow pilots navigating this reach. The project should be constructed from upstream to downstream. The two weirs and the chevron along with the bankline notching of Dike 81.85 L should be the first phase. The notched extension of Dike 81.85 L and the addition of Dike 81.65 L should be the second phase. The construction of the Dikes 80.7 L and 80.6 L should be the third phase.

4. Interpretation of Model Test Results

In the interpretation and evaluation of the results of the tests conducted, it should be remembered that the results of these model tests were qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodible variables. Flood flows were not simulated in this study.

This model study was intended to serve as a tool for the river engineer to guide in assessing the general trends that could be expected to occur in the actual river from a variety of imposed design alternatives. Measures for the final design may be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirements.

FOR MORE INFORMATION

For more information about micro modeling or the Applied River Engineering Center, please contact Robert Davinroy, David Gordon or Dawn Lamm at:

Applied River Engineering Center

U.S. Army Corps of Engineers - St. Louis District

Hydrologic and Hydraulics Branch

Foot of Arsenal Street

St. Louis, Missouri 63118

Phone: (314) 263-4714, (314) 263-4230, or (314) 263-8090

Fax: (314) 263-4166

E-mail: Robert.D.Davinroy@mvs02.usace.army.mil

David.Gordon@mvs02.usace.army.mil

Dawn.Lamm@mvs02.usace.army.mil

Or you can visit us on the World Wide Web at:

http://www.mvs.usace.army.mil/engr/river/river.htm

APPENDIX OF PLATES

Plate #'s 1 through 46 follow:

28. Alternative 7
29. Alternative 8
30. Alternative 9
31. Alternative 10
32. Alternative 11
33. Alternative 12
34. Alternative 13
35. Alternative 14
36. Alternative 15
37. Alternative 16
38. Alternative 17
39. Alternative 18
40. Alternative 19
41. Alternative 20
42. Alternative 21
43. Alternative 22
44. Alternative 23
45. Alternative 24
46. Alternative 25